Brain Actuated Wheelchair Using Neural Signals as an Assistive Home Technology

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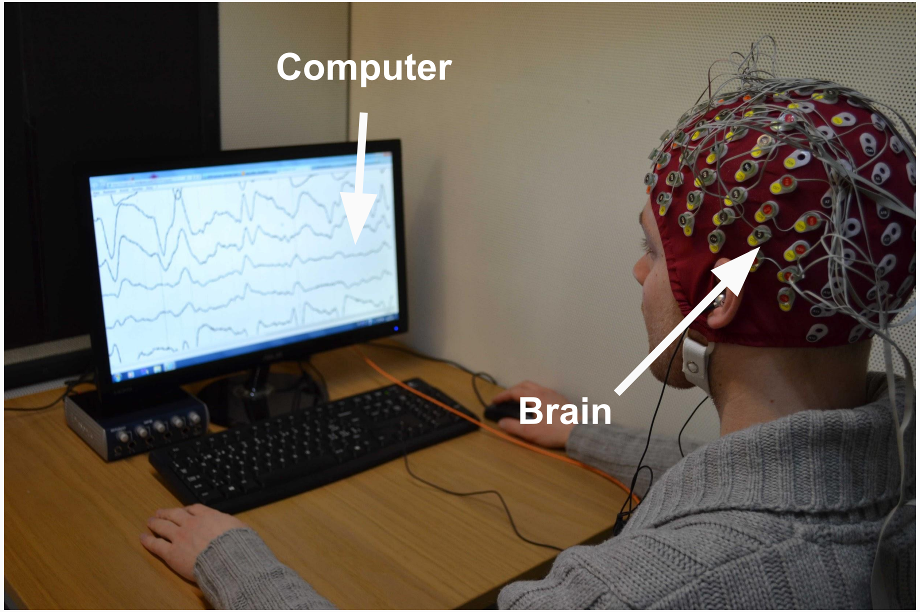
What is BCI? (Brain Computer Interface)

- Invasive
- Noninvasive
  - **EEG**
  - MEG
  - ECoG

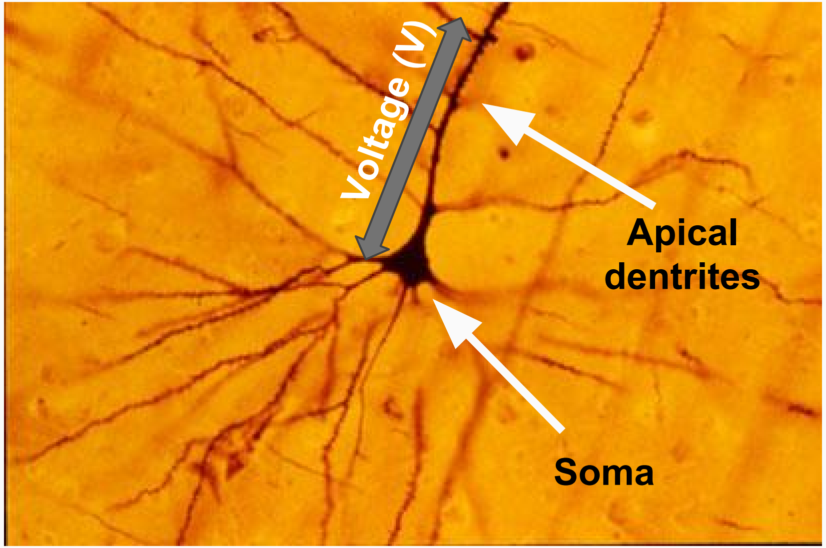
EEG (**E**lectro**E**ncephalo**G**raphy) is a medical imaging technique that reads scalp electrical activity generated by brain structures.



BCI example (EEG)

How signal is generated?

Signals are differences of electrical potentials between **soma** (body of neuron) and **apical dendrites** (neural branches).

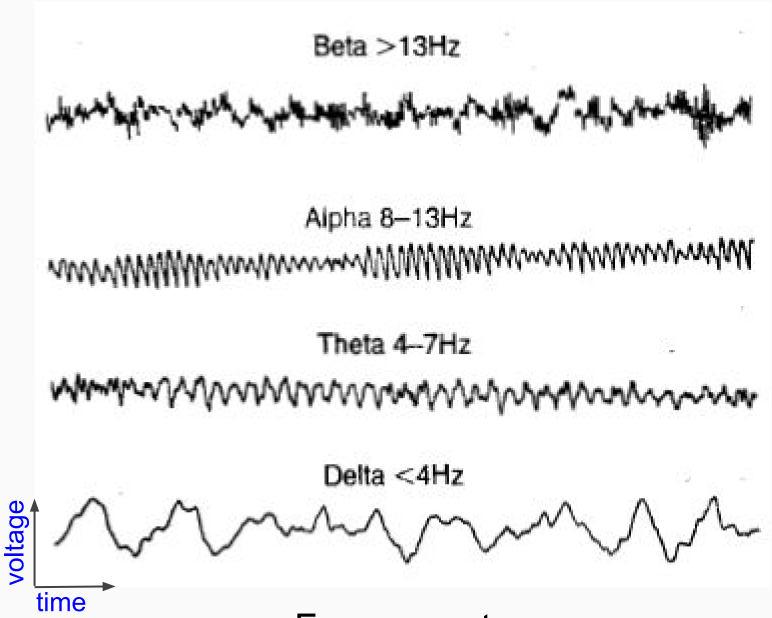


Neural Cell

Frequency bands

The most important frequencies from the physiological viewpoint lie in the range of 0.1 to 30 Hz.

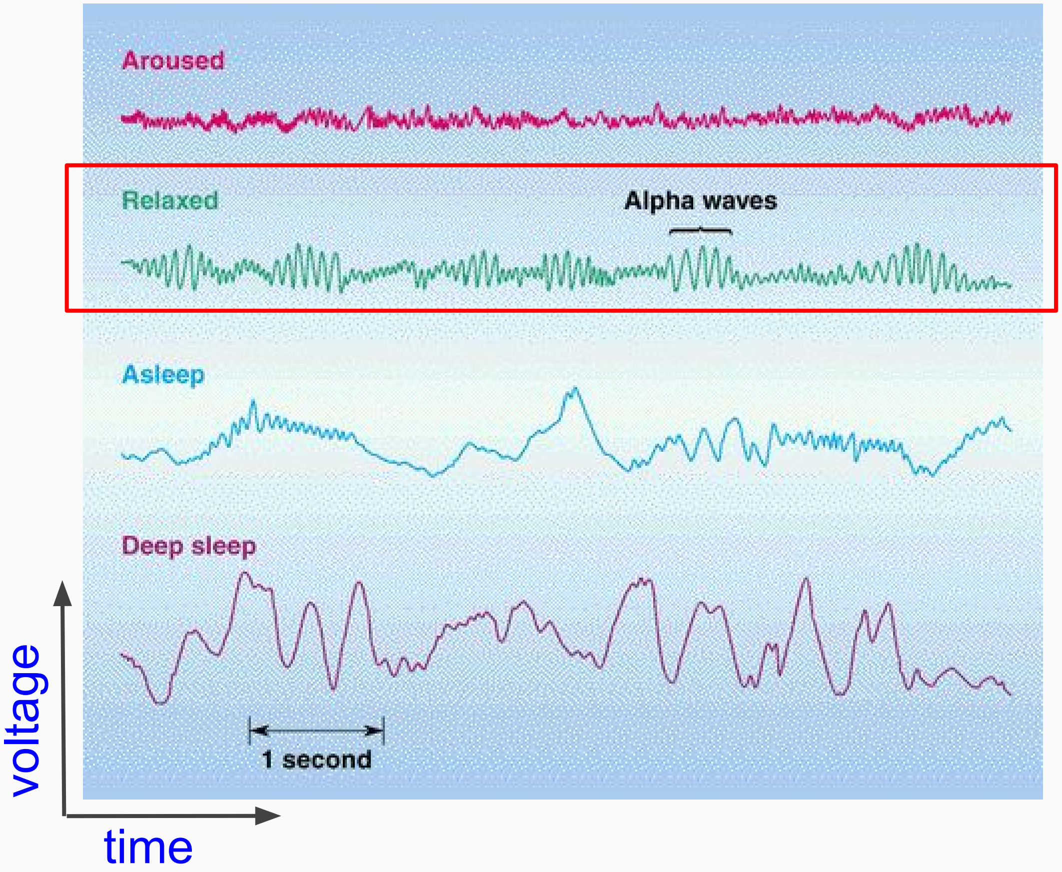
- Delta (δ): $0.5 \le f < 4$ Hz;
- Theta (θ): $4 \le f < 8$ Hz;
- **Alpha (α): $8 \le f \le 13$ Hz**;
- Beta (β): $f > 13$ Hz.



Frequency types

Frequency type characteristics

We are mostly interested in neural oscillations in the frequency range of 8-13 Hz, which are also known as **Alpha** waves.



Beta (14 - 30 Hz)

Alpha (8 - 13 Hz)

Theta (4 - 7 Hz)

Delta (0.5 - 3 Hz)

Internationally standardized 10-20 System

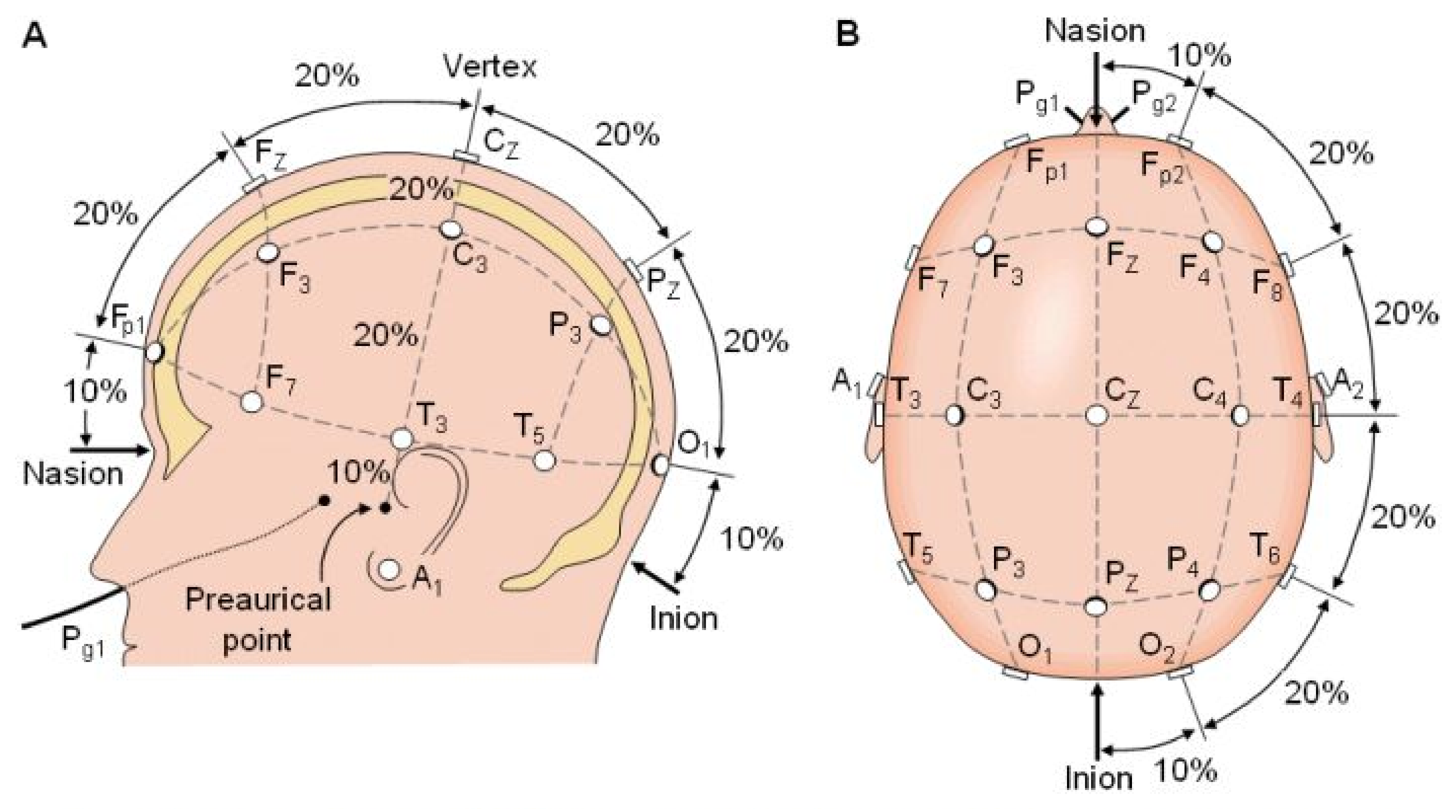


Figure 2. The international 10-20 system seen from (A) left and (B) above the head. A = Ear lobe, C = central, Pg = nasopharyngeal, P = parietal, F = frontal, Fp = frontal polar, O = occipital.

BCI applications

BCI Speller

BCI Game Control

BCI Robotic Arm Control

Wheelchair Control with BCI

Tanaka et al. 2005

Wheelchair Control with BCI (Specifications)

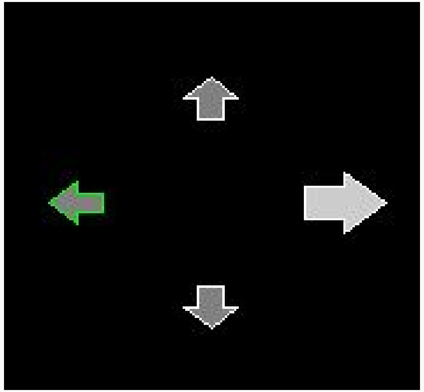
- Robot Jaguar instead of real wheelchair
- Visual Interface -- video from robot camera
- Simple Commands: **Go, Left, Right, Back.**

Technologies used

- Emotiv Epoc BCI
- Jaguar 4x4 Wheel Robot
- buffer_bci framework

ERP (**E**vent **R**elated **P**otential)

- **ERP** -- synchronous (**external stimuli**)
- ERSP -- asynchronous (imagination)
- Location of response depends on modality of stimulus: **visual**, tactile, auditory
- P300 -- visual stimuli (arrow flashes)



Visual stimuli

Artifacts (Noise)

- Bad channels
- Slow electrode drifts
- Eye movement/blinks
- Muscle movement
- Relaxation (deep breath) / stressed
- Very subject and session related

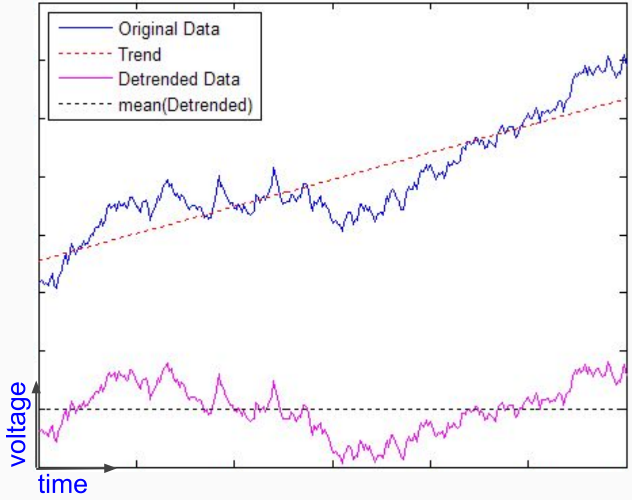
Remove artifacts → Signal Processing

- Detrending
- Bad-channel identify and remove
- Re-referencing/Spatial Filtering
- Spectral filtering
- Bad-trial ID & remove
- Classifier Training

Detrending

Problem: Slow drifts and trends mess the signal

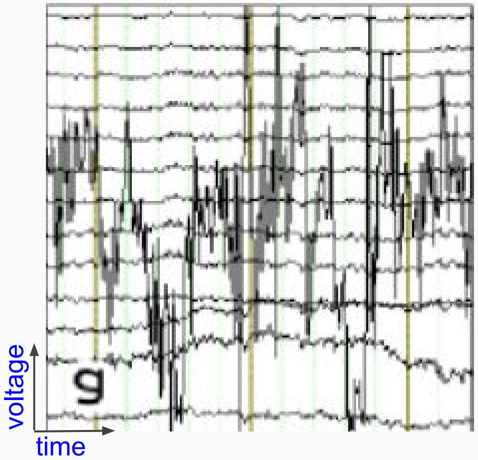
Solution: Compute best-fit line and subtract from the signal



Bad channel identify and remove

Problem: Some channels doesn't work and create only noise

Solution: Identify channels with excessively high power and remove them



Bad channel example

Spatial Filter

Problem: Common noise (e.g. noisy/cold place) affects all channels which mess signals

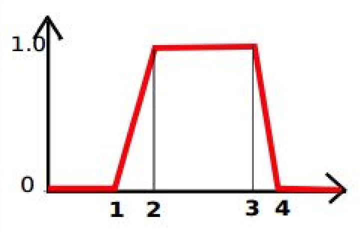
Solution:

- **CAR** (*Common Average Reference*). Remove average signal from all channels
- **SLAP** (*Surface Laplacian*). Remove channel correlation and local average signal

ERP Spectrally Filter

Problem: We are only interested in a given frequency range

Solution: Apply a spectral filter to remove frequencies outside the range of interest



Spectral filter

Bad trial identify and remove

Problem: Noise after eye blink and other artifacts cause mistakes in signal which results in bad classifier

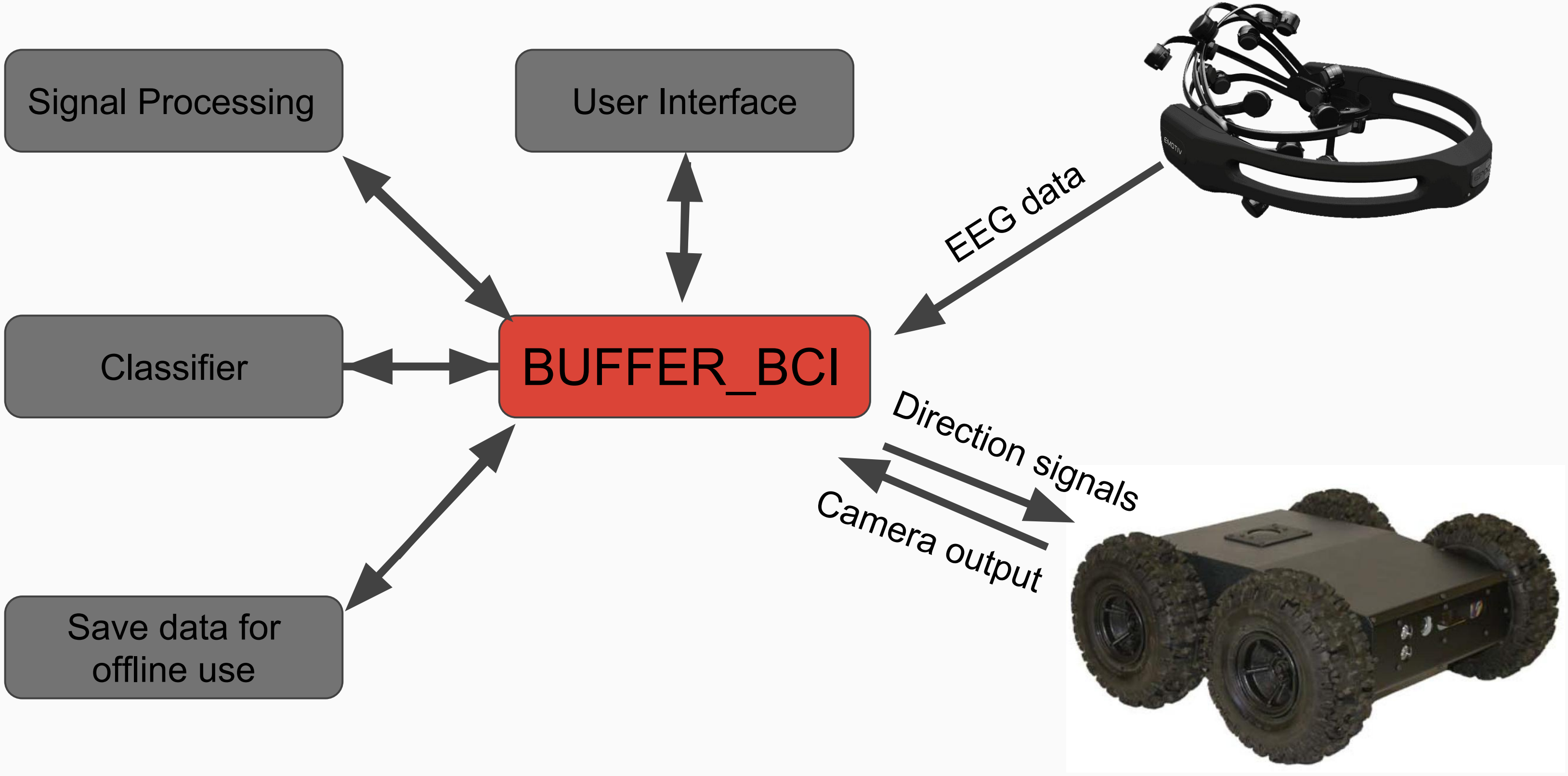
Solution: Identify excessively high power signals and remove them

Train classifier

Problem: We need a classifier model to predict user intention with high accuracy

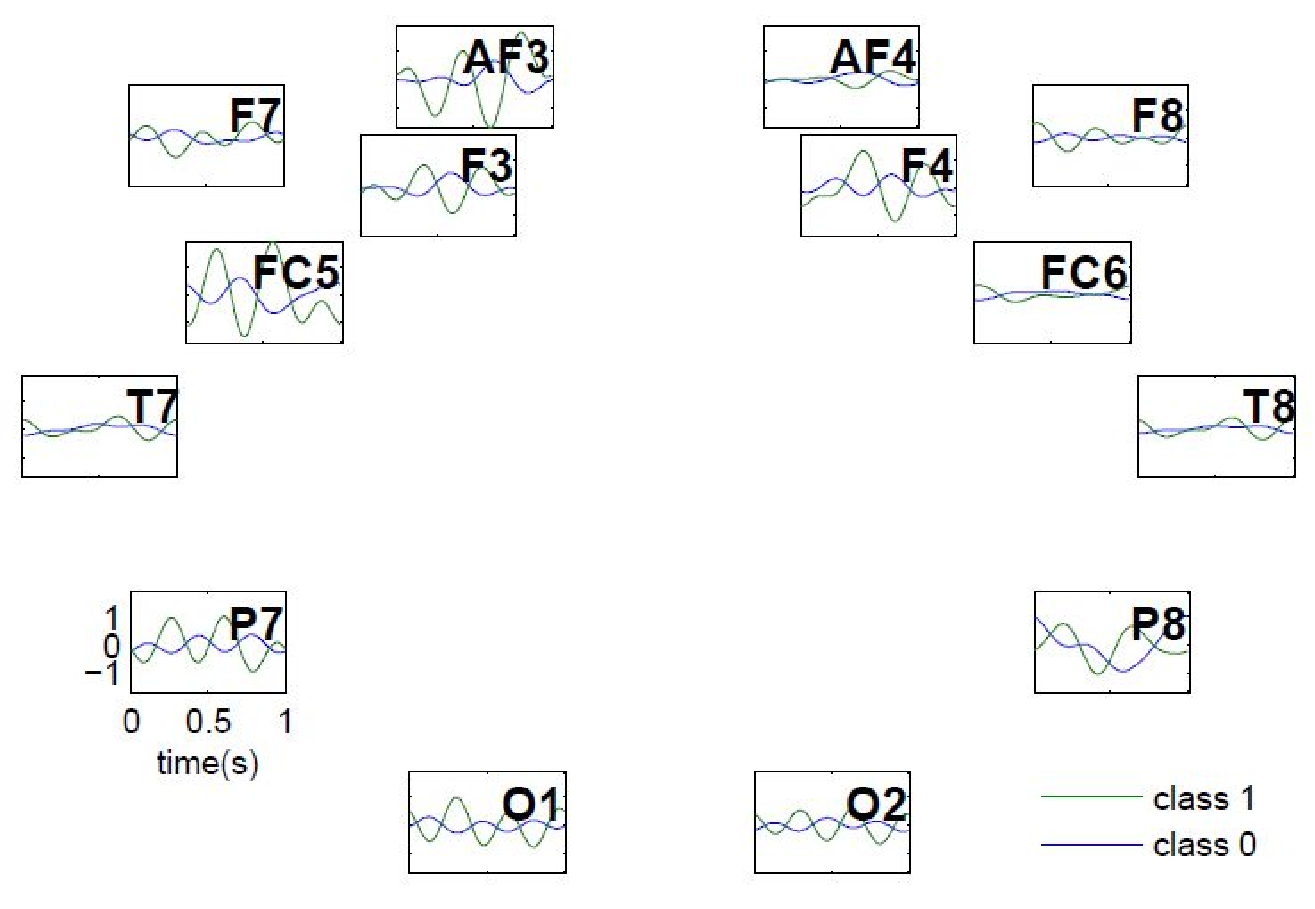
Solution: Use regularized logistic regression on training data

System Architecture



Video demo

Results (ERP data)



Results

- Final testing. 5 persons tested our system.

Subject	1	2	3	4	5
Successful movements	7/16	6/16	7/16	8/16	9/16

Offline classification validation (average): 54.2% (from training data)

Practical classification rate: 46.25% (testing)

Limitations

- Bad accuracy and inconsistency of signal
- Lack of conductive gel (we used saline solution)
- Sensor arrangement (Not designed to read EEG from central and parietal lobes)
- Different main application of Emotiv Epoc
- Time constraints and problems regarding user’s concentration

Potential Future Work

As a future work we can:

- Try other BCIs, which could meet the requirements of our system better than Emotiv Epoc
- Improve interface and try to combine P300 with SSVEP or MI
- Collect data from disabled people and see if our system is applicable to them

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Thanks